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FOSSILS AND FOSSILIZATION.

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IV.

(*Continued from p. 33.*)

As regards their degree of preservation the nature of the deposit has some influence upon the condition of fossils; and the nature of a deposit involves also a suggestion of its position, as we have seen, whether subject to estuarine vicissitudes, tidal fluctuations, or the ceaseless attrition of shore waves. When we examine the sandy and gravelly deposits of the Potsdam (Cambrian), the Medina (Upper Silurian), the Chemung and the Catskill (Devonian), the coarse conglomerate of the Lower Carboniferous, or the calcareous grits of the Schoharie and Oriskany (Lower Devonian) we find a reflexion of their physical character in the condition of the fossils preserved in them. The trilobite layers of Wisconsin and Minnesota in the Upper Cambrian (Potsdam) are crowded with the separated parts of these crustacea, whose delicate articulations were unable to resist the friction they were exposed to in the motions on a beach of siliceous sand. Neither does a sandy beach receive impressions with ease and certainty, as the indistinct outlines of the trilobites in these beds show. Furthermore, in a siliceous bed, more or less percolated through by water, the water has dis-

solved the calcitic or lime parts of these animals, since they were not protected against this depletion by the presence of a calcareous matrix, unless, as with *Obolella polita*, at Trempeleau, Wisconsin, the great numbers of the fossil itself acts as a protection against solution and attrition. The influence of a slight admixture of a plastic ingredient in improving the casts and impressions of fossils is seen in the more argillaceous layers of the Cambrian beds, as at Mazomania, Wisconsin, where *Aglaspis barrandii* and *Dicellocephalus minnesotensis* are retained with a firmer and more legible outline. In many layers the Obolellas are broken, and appear as shelly fragments scattered over the rock. The Obolella is also a compact and small object, protected to some extent by the convexity of its valves; but where it is preserved in perfection we may reasonably conclude, like the little *Gemma gemma* of our coasts, it had buried itself in the sand, and was not expelled from its safe position by waves or denudation. The regular close distribution of these fossils over the slabs of Potsdam sandstone show that they suffered little or no displacement. On the other hand, the fragments of Ptychoparia (trilobite) in the same rocks at Trempeleau, Kickapoo, prove from their heterogeneous, confused interference of parts, some drifting, rubbing and dislocation. The *Lingulepis pinniformis*, a delicate shell, and with valves held together by ligaments alone, occurs in great numbers in the sandy Potsdam beds of St. Croix, and in a very good state of preservation; in some instances, the concentric lines of growth, the polished and corneous surface being retained. But, for the most part, the individual shells have suffered from friction and breaking. *Lingulella stoneana* in the red beds of Mazomania are flattened and disfigured. But in the green slates of Braintree, Mass., *Paradoxides harlanii*, a trilobite, is well preserved, except where distortion from compression and lateral motion has strained and deformed the parts. Similarly another crustacean, *Olenellus*, in the less dense slates of Georgia, Vt., also Lower Cambrian, is found quite well preserved, but suffering mutilation and almost obliteration at times, from the metamorphic pressure by which these aluminous muds were transformed into fissile shales. In the annelid, green paper shales of Waterville,

Kennebec River, Maine, the serpentine markings of what has been referred to a worm are well preserved. In the Medina sandstone, a red ferruginous sandstone of the Upper Silurian age, the fossils are poorly preserved, lacking fullness of contour and seldom showing the surface characters with any distinctness. Lyell collected oyster shells and Buccinum thrown up by a storm on the shore of the estuary of the Forth, Scotland, and observed that "although still living, their shells were worn by the long attrition of sand which had passed over them, as they lay in their native bed, and which had evidently not resulted from the mere action of the tempest, by which they were cast ashore." The fossils of the Medina sandstone show abrasion, and in most cases present a rude cast of sand, made by the filling in of the shell, without muscular markings, and often with shrunken outlines, as if the sand filling had contracted. Wet sand, occupying the interior of a shell, must, upon drying, undergo some contraction, and being less apt to contract equally than clay or a calcareous paste, reproduces its mould less perfectly. The finer grained sandstone, however, and those somewhat more coherent, from the intermixture of lime or clay, are better adapted for the retention of fossil bodies and impressions. Thus, the Chemung sandstone (Upper Devonian) is a variable mixture of sand and carbonate of lime, and is introduced in a series of shales and siliceous limestones, whereby, as it formed a contiguous beach deposit to these, it became a repository of fossils, and was from its constitution better adapted to retain them. Mosely observed in the beach of Little Saba Island that there was being formed a reddish sandstone conglomerate rock, made up of the débris of the rock of the higher parts of the island cemented together by calcareous matter, derived from the corals and calcareous sand. And in this forming mass, which made a hard compact rock, there were embedded "plenty of the various corals from the beach, and large Turbo shells (*T. pica*) with their nacre quite fresh in lustre, and their bright greenish color unimpaired." Something similar is seen in the Chemung flagstones, and in the fossiliferous layers of this group of beds the organic remains are plentiful and well preserved. In the Catskill sandstones, which

vary greatly in their texture, but generally are coarse and irregular in grain, we find the evidence of unfavorable conditions for fossil remains in the comminuted fish bones and scales, except where massiveness precludes such dislocation and fracture, as with the shoulder plates of large Antiarcha (*Bothriolepis taylorii*).

The fresh water bivalve, *Amnigenia catskillensis*, is found in the Chemung beds, in the shaly stratum known as the Oneonta sandstone, at Mt. Upton, Chenango Co., N. Y., and in the Catskill beds higher up, where it is embedded in sandstone. The state of fossilization in these two different positions is somewhat contrasted. The shells of this species in the magnesian slate, which has been a softer and less injurious matrix than the sandy layers of the Catskill girt, are well preserved, indicating a thinner and less corrugated shell than its representatives in the sandstone. The shell has here been kept entire, as in a replacement wherein we have the pseudomorph of the two valves in juxtaposition, the waving and somewhat confluent lines of growth conspicuous, and the thin, fragile expanded margin preserved, whereas in the sandstone the impressions of the surface are less clear and distinct, and the shell-body cannot be removed by itself, as in the type specimen from these softer and less sandy beds.

Fossils are well preserved in the slates, which, from their fine texture and mechanical homogeneity, take impressions easily. But in this group of deposits pressure has acted unfavorably in many instances, and the fossils have suffered distortion and compression. Many of our fossiliferous slates, as the Utica, Marcellus and Genessee, are dark-colored from carbonaceous admixtures, and the fossils in them partake of their color, which, in a measure, destroys their perfection and usefulness. Again, pyrite in many instances has been precipitated by organic reduction over the surfaces of fossils in these beds, and the fossils then appear coated or replaced by this yellow sulphide, by which they are made conspicuous upon a black background. The interesting sponges of the Utica Slate are by this means beautifully retained as a network of metallic threads and fronds, reticulating meshes of pale gold (*Cyathophycus subsphericus* and *C. reticulata*).

The limestone formations which represent the accreted deposits of foraminiferous ooze, shells, and the lime paste made by the solution of shells, contain fossils in great abundance, and yield excellent specimens. But specimens in individual perfection, such as are extracted full and free from their matrix, are mainly obtained from impure limestone rocks. The admixture of clay or sand differentiates as it were the matrix from its included fossils, and they seem less consolidated and blended with the surrounding rock, so that their outlines form boundaries of separation, and the fossils are picked out complete, quite disengaged from any adhering stone. Such beds as the Hudson River Slates, the Waldron beds of Indiana, the Hamilton layers in New York, the Lower Carboniferous shale at Crawfordsville, Indiana, are illustrations of a fossiliferous rock from which the fossils become detached, retaining their surface characters and a clean, hardened epidermis, from which every particle of rock can be separated. In siliceous limestones, like the Schoharie Grit, the Oriskany Sandstone, and the Calciferous beds along Lake Champlain, the fossils are revealed by weathering, whereby the limestone seems displaced by solution in surface waters, or slowly lifted from the contour of fossils by frost decrepitation, and the fossils remain as partial or entirely siliceous reliefs. Prof. Perkins, of Vermont, has found productive quarries of fossils under growing trees, where the vegetable acids have disintegrated the calcareous portions of these beds, and left the silicified fossils in complete relief or entirely free, as if shaken out from the enclosing envelopes of rock. In hard limestones this surface weathering often takes place, a sort of aerial development, by which the valves of shells, the spines and members of trilobites, the stems and plates of crinoids, slowly emerge and stand out on a rock, whose interior faces only reveal a poorly discerned outline of fossils, until they have undergone this atmospheric alteration. The fossils themselves appear to have resisted the attack of acid waters and frost from having a greater density, upon which these agents of change failed to act, or from having become silicified in the process of change. In many of these beds the fossils are colored by iron oxide, caused by weathering, from a protoxide to

a sesquioxide, and so the contained remains of animals are changed from a blueish gray to a ferruginous yellow, and become more conspicuous. Fossil shells possessing a smooth, compact surface seem to have often escaped disintegration, while the surrounding matrix was removed, because they afforded no absorptive surfaces for the retention of the dissolving infiltrations of acid waters. It must also be borne in mind that the changes which limestone beds undergo from secondary crystallization, produced by the geognostic conditions of pressure, heating, etc., affect all their contents, and develop a crystalline structure in which the fossils become scarcely recognizable.

Invertebrate fossils occur as moulds, casts, or entire shells and bodies, according as they have left their impressions in the soft sediments amidst which they lay, or have been filled by the penetration of the ocean mud, so as to have produced a complete cast of their entire interior shape and markings; or, lastly, as they have been petrified throughout, and remain as they were deposited, retaining their exterior shell or integuments, and presenting when extracted a stone counterfeit of the original organism. Of course, for the most part, in such a process of petrifaction all interior structure is destroyed. But this is not universally the case, and many important interior appendages are sometimes preserved in exquisite perfection, or, at least, so far preserved as to afford instruction to the palæontologist. This preservation is determined by the nature and substance of these parts, and depends also upon the mineral conditions existing during the fossilization of the animal. Thus, the brachial appendages of *Orthis*, *Strophomena* and *Productus* are of such a soft and fleshy texture as to be unable to resist change long enough for their conversion into a mineral framework, although their impressions are found, whereas with *Spirifera*, *Terebratula* and *Atrypa* these delicate spirals and loops, upon which the breathing arms are supported in the chamber cavity of the shell, are preserved in a siliceous reproduction. Again, a sandy deposit will seldom permit the perfect preservation of fragile portions of the animal, nor induce that gradual replacement of its calcareous structure by

silica, such as has evidently taken place in the corals of the Upper Helderberg limestone. An exception occurs in the Brachiopoda of the very sandy loosely coherent beds of the Oriskany sandstone at Cumberland, Maryland. In pocket-like cavites at this locality in the sandstone the molluscan remains are found beautifully preserved in silica, doubtless owing to the supersaturation of infiltrating waters with colloidal silica. The muscular bundles, the vascular markings of the circulating system, the punctate surface of the mantle in mollusca are, however, well retained in siliceous muds or sandy limestones, and surpass in usefulness similar indications in limestones, where incipient crystallization has destroyed these by knitting both shell and its contents into a crystalline unit.

Fossils are frequently removed by solution in carbonated waters, and possibly in waters carrying organic acids, as suggested by Dr. Julien, when "in porous masses of gravel, sand and clay" they become subject to saturation in such menstrua. Hilgard has shown the protective influence of an argillaceous matrix, for in the Tertiary deposits of the Southern States the shells were only partially destroyed in the clay layers, while calcareous concretions, made by the liberated lime from the dissolved fossils, were frequently in the more porous portions of the deposit. In the Palæzoic sandstones generally shells are less common than the impressions, moulds and casts, and a similar process of obliteration may have removed them also.

The replacement of invertebrate fossils by mineral pseudomorphs or substitution is a very interesting and important subject, and remains yet a peculiar method in the economy of nature. While it is true that silicification, or the replacement of organic structure by silica, is the most common and the most satisfactory form of this change, yet a number of other mineral species become transferred in organic bodies to the places occupied by the molecules of organic tissues, or of the carbonate of lime shells. In the Lower Silurian beds of the Galena limestone, in Wisconsin, fossils assume the substance of sulphide of lead (Galenite); and in Cornwall fragments of antlers, containing tin oxide, are found, wherein "the original structure seems to be almost entirely reproduced as cassiterite" (Phillips).

In the Coal Measures the fossil mollusca (*Solenomya, Macrocheilus Orthoceras Bellerophon*) are often found as earthy casts coated with a skin or shell of iron pyrite. Limonite, the hydrated sesquioxide of iron, reproduces the shells of *Atrypa, Beyrichia, Dalmania,* in the Clinton iron of the Upper Silurian, in Oneida Co., N. Y., while Malachite, Sphalerite, Sulphur, Barite, Celestite, Fluorite, Calamine, etc., in an imperfect way replace the shells or coverings of fossils, fill their interiors, and rarely take on the resemblance of their tissue and texture.

The silicification of fossils in its simplest expression is the substitution of the mineral quartz—silica—for the molecules of the shell of an organism, or for those of its hard or horny anatomy. The exact steps by which this alteration is effected are not clearly known, and of the many hypotheses offered to explain this phenomenon all may have some elements of truth. It was observed long ago by Von Buch that this silicification followed the organic structure.

It is certainly true that organic matter, if of some consistency, possesses some power of arresting silica, fixing it, as it were, by removing it from aqueous solutions. Le Conte suggests that at least in the case of wood an alkaline silicate in water is neutralized by the humic acid of the decomposing vegetation, by which the silica of the salt is precipitated in the pores of the wood, and the wood fibre, as humic acid, is removed as the silica assumes its position. This seems to imply too much incipient decomposition to be reconciled with the very perfect microscopic manner in which wood texture is replaced by an agate pseudomorph. Dr. Julien has laid great stress upon the important silicic compounds of vegetable or organic acids in producing colloidal silica replacements. This view seems to be that " during the decomposition of the sarcode of both animal and vegetable organisms, after death, gelatinous or colloid substances are generated, resembling *glairine,* which are soluble in sea water, which combine with silica, and may therefore convey and concentrate it, dissolving its particles disseminated through submarine sediments, and which may, in forms produced by gradual oxidation, act also as acid solvents of lime, oxides of iron and manganese." A similar explanation, though

somewhat more simple, is, that in siliceous rocks, or in positions where calcareous fossils are exposed to siliceous waters, the terrestrial waters carrying silica, which may have entered into solution through its union with organic bodies, dissolve these fossils by their contained carbonic anhydride, and this assumption of a new burden diminishes their carrying power of other dissolved contents, and these latter are dropped at the exact moment the new solution is effected. Or, as carbonate of lime is taken up in solution silica is deposited. In the phenomenon of solutions and solvents this equilibrium of dissolved contents perhaps is not clearly proven, but seems in some cases probable.

(*To be Continued.*)

BIRD LIFE IN CENTRAL AMERICA.

By Daniel F. Randolph.

A short time ago a friend of the writer was in Central America for the purpose of studying the country and its peculiar people. Ornithology is a hobby of his. Upon his return, I induced him to give me an account of his trip, which he did. The following is a transcript of my shorthand notes of his talk.

"I remember," he began, "that about the shores of the lagoon where I spent considerable time, there were great numbers of a handsome rail, which was very delicate eating, the flesh being milk white. It has a habit of skulking under the reeds and bushes on the shores during the day, and sometimes, when congregated in marshy places, makes a great noise by chattering in chorus. When shot, this bird goes through more contortions than any other bird I know of, not running away when wounded, but invariably tumbling on the ground, kicking and fluttering about in the most violent manner.

"A large red-breasted kingfisher is very common in all the lagoons and the lower part of the rivers; and blue and white garlings are seen on nearly all the shoals and creeks.

"I went along the sea-beach (by a little lagoon), among the